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EDUCATIONAL RESEARCH RELATED TO SCIENCE INSTRUCTION FOR THE ELEMENTARY AND JUNIOR HIGH SCHOOL - A REVIEW AND COMMENTARY.

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SIGNIFICANT EDUCATIONAL RESEARCH RELATED TO ELEMENTARY AND JUNIOR HIGH SCHOOL SCIENCE TEACHING IS REVIEWED. OUTSTANDING DEVELOPMENTS IN THE HISTORY OF ELEMENTARY AND JUNIOR HIGH SCHOOL SCIENCE TEACHING AFTER 1850 ARE PRESENTED. GENERAL TYPES OF STUDIES INCLUDED IN THE SURVEY ARE DESCRIBED IN AN OVERVIEW OF THE RESEARCH IN SCIENCE EDUCATION DURING THIS SAME PERIOD. MAJOR CATEGORIES OF RESEARCH STUDIES INCLUDE (1) AIMS AND OBJECTIVES, (2) CURRICULUM, (3) TECHNOLOGY APPLIED TO SCIENCE INSTRUCTION, (4) TESTING AND EVALUATION, AND (5) TEACHER EDUCATION. SUBCATEGORIES OF CURRICULUM ARE (1) CONTENT AND GRADE PLACEMENT, (2) PROBLEM SOLVING, (3) CONCEPTS AND PRINCIPLES, (4) STUDENT INTERESTS, (5) READING DIFFICULTIES, AND (6) ENRICHMENT PROCEDURES. SUMMARIES OF SPECIFIC STUDIES INCLUDE BRIEF STATEMENTS OF PURPOSE, METHODOLOGY, AND FINDINGS. COMPLETE CITATIONS OF THE STUDIES REVIEWED ARE INCLUDED. THIS ARTICLE IS PUBLISHED IN THE "JOURNAL OF RESEARCH IN SCIENCE TEACHING," VOLUME 1, NUMBER 3, SEPTEMBER 1963. (AG)

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In the summer of 1962, Professor Herbert Smith of Pennsylvania State University was requested by the Commission on Science Education of the American Association for the Advancement of Science to prepare a paper summarizing reports of the most significant educational research relating to the teaching of elementary school and junior high school science. The purpose of this project was to make available to members of the Commission and others interested in the current efforts to improve science education the results of that research which has influenced most heavily current educational practice and which should therefore be of interest to those seeking to change present practice. A draft of the report was used by participants in the writing session held under the auspices of the AAAS Commission on Science Education at Stanford University in the summer of 1963. The JRST has agreed to assist in efforts to bring Dr. Smith's paper to the attention of the science education community and the Commission has expressed appreciation to the JRST for this service. The opinions expressed do not necessarily represent AAAS, its Commission on Science Education, or the JRST. Reprints are available from the Editor, Department of Science Education, The Florida State University, Tallahassee, Florida, at a cost of $0.50 per copy.

Educational Research Related to Science Instruction for the Elementary and Junior High School: A Review and Commentary

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Prologue to the Report

The preparation of the review summarized in this report has been both a challenging and a frustrating experience. One is constantly plagued with the certain knowledge that he has left much unsaid. The discourse skims lightly over the sacred precincts of philosophy and psychology. The valleys of contention have been noted and passed by; no man's banner has been waved; and the writer knows perfectly well that dozens of worthy studies have not been mentioned. It is apparent, too, that some significant areas have not been touched at all and others have been considered only in most perfunctory fashion. In spite of this, the report is more comprehensive than the writer was directed to submit.

In an effort to make the report useful to individuals who are not acquainted with educational research or even familiar with elementary education, a much greater degree of editorial license has been taken to criticize, comment, question, and summarize than is usually permitted to a reviewer. Such license will no doubt reap its own reward for the reviewer through the contumely of his critics. To such critics, the writer shall offer only one rejoinder: "Go and do better."

So fast is all technology moving these days that by one estimate new engineering graduates can expect a professional "half life" of only about ten years. Half of what they now know will be obsolete in 1973, and only half of what they will need to know is available to them at this time.

Time, May 3, 1963, p. 88

Introduction

Most of the research in social science is a 20th century development. Since education is an applied field, it is not surprising that research in education did not develop until after progress had been made in the basic disciplines of psychology, sociology, and anthropology; and after these areas had become established as appropriate fields for research. These observations are intended to indicate the relative infancy of the field of education as a subject for the kind of intellectual inquiry known as research.

It should be apparent from this paper that much progress has been made in educational research from the first tentative, uncertain, and naive approaches to the rather complex designs and procedures now frequently encountered. Sophisticated notions of design and analysis are now available and are being applied to the problems of education. It is also obvious that a very elastic definition of research has been all too commonly employed, and that activities under this rubric embrace efforts from the most complex and sophisticated to the most elementary, if not trivial, procedures. This paper provides an abbreviated introduction to the research pertinent to science instruction at the elementary and junior high school levels.

Historical Background

The roots of the modern American elementary school science program can be traced through their development of more than 100 years. Two definite influences can be identified as early as the decade of the 1850's. One of these was the didactic literature brought into this country largely from Britain and adapted and then reprinted by American publishers. This instructional literature reflected its origins in an aristocratic conception of education and was designed for use by private tutors or by parents teaching the children at home. It was within the financial reach of only the upper classes. Most of this material was directed to children's observation and to study of natural phenomena. Underhill has traced the didactic literature to the influence of such men as Francis Bacon, John Locke, and other writers who at that time were stimulating democratic thought in Europe as well as in America.[1] When the National Education Association was organized in 1857, it helped to stimulate the task of adapting some of this literature for use in school classrooms.

The second influential factor during the late 1850's rose from the "Pestalozzian object teaching" movement. This method of teaching was very widespread and was an international educational development. The applications made of the method varied greatly from one country to another. In Germany it developed into *Heimatkunde*,[2] or "community study." In England and in the United States object teaching evolved into, and was later supplanted by, nature study. However, the American and English versions of nature study varied greatly in spite of their common origin in object teaching.

The best known American adaptation of the Pestalozzian method was developed at Oswego, New York. Due to the influence of the National Education Association which supported it, the "Oswego method"[3] was given nearly universal acceptance in this country. The new method aroused interest in the revision of content and in the method of study in the rapidly growing elementary schools.

The methodology of object teaching had a highly formal structure which tended to obscure the legitimate purposes of science instruction; it did not contribute effectively to a sense of sequence and direction. Men like Franklin and Jefferson had encouraged the development of science in elementary education hoping for and working for programs that had merit due to their continuity and practicality. Object teaching destroyed whatever gains had been made in this direction because the emphasis tended to shift to mere description of animate and inanimate objects and to neglect the interpretation and understanding of events and phenomena. The content was further fragmented by the organization of information concerning the particular object of study into formal separate sciences, thus imposing a mature scientist's view on children. Profound meanings tended to be neglected in favor of mere obvious descriptions.

The old method of object teaching tended to be supported by the principles of faculty psychology.[4] The emphasis on observation and memorization for very young children was based on the assumption of the sequential development of capacities. It was falsely assumed that young children were able only to observe and identify objects but were unable to reason or to interpret phenomena. In addition, the specialized methodology of object teaching, together with the exclusion of the use of books, made heavy demands upon the ability and knowledge of the teacher. It appeared to be particularly ill-suited to the purposes and needs of teachers and pupils in a rapidly developing industrial society.

Some insight into the nature of the ideas underlying the "object study" movement may be gained from the following selected excerpts. The method was:

> to place objects before them [children] in which they are interested, and which tend to cultivate their perceptive faculties; and, at the same time, lead them to name the object, to describe its parts, and to state the relation of these parts. Thus language also is cultivated; and, from the observation of a single object, the pupil is led to compare it with others, and the first steps in classification are taken.
>
> ...These lessons are designed specially to cultivate the perceptive faculty; and hence, in any true system of education, they must be considered as fundamental—not only in their relation to the faculties, but as giving the first ideas, or laying the foundation of all branches of knowledge. Object Lessons in form lead directly to Drawing, Writing, and Geometry; in sound and form, to Language, including Reading, Speaking, and Spelling; in place, to Geography; and in animals, plants, minerals, etc., to Natural History...
>
> This method commences with an examination of objects and facts, then institutes comparisons by which resemblances, differences, and relations are observed; and with the results so obtained, repeats the process until the remotest relations are known and the highest generalizations reached. This process may, with propriety, be called the Objective Method or Objective Teaching.
>
> Objective Teaching, in this enlarged sense, includes Object Lessons, and a great deal more. It comprehends the unfolding of the faculties in the order of their growth and use, and the presentation of the several branches of instruction in their natural order. Its great aims are mental growth and the acquisition of knowledge.[5]

The decade of 1870 witnessed the culmination of a number of developing trends. The writings of such men as Herbert Spencer[6] in his essay, "What Knowledge is of Most Worth," and the rising importance of science and technology had forced the consideration of science as a field of study upon the public. It was during this decade that colleges and universities first came to accept science subjects as satisfactory prerequisites for admission to colleges.

The depression of 1873 spurred a critical examination of the program of the public schools; and the elementary schools, particularly, were the object of a veritable storm of abusive criticism. Tax-conscious citizens were demanding clarification of the aims and purposes of education. Most of the educational journals joined the hue and cry for more science in the public school programs. There were accompanying changes in the social and economic patterns of the time. Old patterns of teaching and learning were seen to be ill-adapted to the changing times and not fully in accord with characteristics of the learning process.

Near the end of the 19th century, the National Education Association sponsored an extensive study at the secondary school level that was to influence the entire educational system. This was the work of the National Education Association Committee of Ten. The results of this Committee's study tended to stabilize science offerings and led to the discontinuance of a large number of short-term specialized science courses taught in the secondary school. The report put emphasis on laboratory and other direct experiences and on the need for special training for science teachers. Its influence was effective primarily on textbooks, syllabi and other instructional material. These changes at the secondary level were reflected rather quickly in the elementary schools. It was only after the report of the Committee of Ten that materials for pupil use and teacher planning appeared in any appreciable volume.

A number of men rose to prominence in the field of elementary school science around the turn of the century. Of these, William F. Harris[4] first translated philosophy and educational theory into a specific and extensively detailed elementary science curriculum which provided help to teachers in the field. G. Stanley Hall[7] and Colonel Francis W. Parker[8] contributed general philosophies of education supporting nature study. These philosophies opened the way for others to experiment and to work out detailed elementary programs, especially in elementary science. Much of this work was done by Henry H. Strait and Wilbur S. Jackman at the Practice School of the Cook County Normal School, later the Chicago Institute, and now the School of Education at the University of Chicago.[1] Parker strongly supported the work of Strait and Jackman in Chicago, influencing the use of science as a unifying principle in elementary school curricula. Jackman's writings represent a connecting link between early writers of children's literature and modern elementary science. His positive, dynamic view of children and science is in close accord with modern ideas. Jackman's contributions to elementary science were obscured for a time by the extended development of a nature study movement.

Liberty Hyde Bailey and associates at Cornell University were prime movers of the nature study movement. They were motivated by the need to improve agriculture and to halt the increasing migration of young people from farms to cities where they would add to already swollen city relief rolls.[9] One of the important publications to come out of Cornell was the *Handbook of Nature Study* by Mrs. Anna Botsford Comstock which ran through many editions after 1911. This book, along with the Cornell rural school leaflets was, and still is, widely distributed to schools. These and other publications by the Cornell group rank among the most comprehensive efforts in teacher education ever undertaken in the field of science education. Like object study, nature study was based on the principles of faculty psychology and on the alleged serial development of traits. The child was considered in terms of his limitations rather than in terms of his capabilities. Nature study had been developed by specialists in science who lacked the perception and understanding of men like Jackman who were specialists in science as well as experienced teachers of children.

By the 1920's the enthusiasm for nature study was beginning to wane. The influence of the new designs in curricula for science was beginning to be felt. In addition, new thinking in other fields was again beginning to make an impact on all of education and was particularly relevant to science instruction. Men of the stature of Charles Sanders Peirce,[10] William James[11] and John Dewey[12] were having tremendous influence on education. William James and Charles Sanders Peirce had contributed a theory of pragmatism which meant in essence that the meaning of a conception is to be found in the working out of its implications. The link between concept and experience was seen as fundamental. Peirce's thinking was basic to the development of the operational theory of meaning which was closely associated with the development of pragmatism. Dewey's contributions were numerous; but, perhaps, the most significant for the developing field of elementary science was his contention that the methodology of science is at least of equal—or perhaps of greater—significance than the actual knowledge accumulated. The present emphasis on "science as inquiry" would seem to be a reaffirmation of a position which Dewey took nearly half a century ago. It was apparent by the middle of the 1920's that nature study was no longer a satisfactory vehicle for a modern science program. Its whole rationale was no longer consistent with the psychology, philosophy and methodology of the time. It was inconsistent with the existing social and economic realities. With the benefit of historical perspective it is patently obvious that a substantial change in the science program for the elementary school was in order.

It is probably no exaggeration to say that Columbia University was, at that time, the colossus of American education as a training institution for public school administration and for other general leadership positions in the educational field. In 1927 a thesis was written at Columbia which came at a time when the situation was ripe for change. It represented the then most prestigious institution in professional education and was to have, perhaps, the most far-reaching influence on the development of elementary science of any single event in the history of the field. The study was entitled *Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School.*[13] It represented the culmination of three years of work by Gerald S. Craig at the famous laboratory school and profoundly affected subsequent developments in elementary school science. Craig turned his back resolutely on the nature study movement and, in so doing, took note of the great chaos of educational goals to which lip service was then being paid. These goals included various esthetic, ethical, spiritual, intellectual, and civil-training goals without adequate indication as to how such aims were to be achieved. Parenthetically, it is perhaps worth noting at this point that the question of purposes is one which is still not fully resolved, although it is certain that there is far more unanimity as to the purposes and ends to be served today than there was at the time that Craig was doing his original study. Some of the present arguments and debates in the profession represent confusion among the disputing parties as to the real purposes to be served by the elementary science program. Craig saw the function of science in the elementary school to be significant in terms of general education, pointing out that the laws, generalizations, and principles of science have vital meanings to individuals regarding numerous questions which confront them. He also saw the utilitarian aspect as it is related to health, safety, and the economy. He was aware, moreover, of more than the cognitive aspects of science instruction and emphasized also the affective dimensions: attitudes, appreciations, and interests. Clearly, Craig's thesis has been one of the landmarks in elementary science and is basic to much of the later writings in the field including his own.

Another important step forward was taken when the Thirty-first Yearbook[14] of the National Society for the Study of Education was published in 1932. This Yearbook presented a plan for an integrated program of science teaching. This marked the beginning of a trend which has continued to be more and more emphasized down to the present time. Problems involving sequence and articulation of science instruction between the various grades and school units have continued as vexing difficulties. The National Science Teachers Association has had a committee at work for several years on the K-12 science program. Others are equally concerned with problems of articulation between high schools and colleges. The design of an appropriate sequential series of science experiences which shall extend from elementary school through college is a problem which has occupied the thinking of many persons. This problem has stimulated study of such diverse questions as content and placement, when track programs should be instituted, when non-science and non-college bound students should terminate their study of science, when advanced placement programs should be used, and how elementary teachers should be educated. These questions are obviously inter-twined with conceptions of the ultimate purposes and goals of education and no universal agreement has been attained as to what these should be. Perhaps no such agreement is possible or even desirable; but an understanding of the problems and their complexities would at least reduce the confusion.

The Thirty-first Yearbook also placed an emphasis on the major generalizations of science as objectives of instruction. This emphasis had profound effects on course syllabi and textbooks, and a generation of these documents tended to emphasize the understandings and applications of the principles of science. One other obvious example of the Yearbook's influence was the great amount of research devoted to identifying the major principles of science which were of significance to general education. In fact, a great body of the research that was subsequently done in science education was a reflection of the influence of this famous Yearbook. The Yearbook was clear and definite in its support of elementary science rather than nature study and, as a result, it contributed to the rapid advancement of science at the elementary school level. The report advocated basing the selection of science content on personal and social criteria; thus, probably, both conforming to and augmenting the educational thinking that was then developing in this direction.

The Society also devoted its Forty-sixth Yearbook, published in 1947, to problems of science education. The increasing impact which science was obviously having upon the social, cultural, and economic affairs of men continued to be very much in evidence in the thinking revealed in this Yearbook. The following quotation is illustrative of this fact.

> Instruction in science must take cognizance of the social impact of developments produced by science. It is not enough that they be understood in a technical or scientific sense; it is most important that their effects on attitudes and relationships of people be studied and understood. Science instruction has not only a great potential contribution to make but also a responsibility to help develop in our youth the qualities of mind and the attitudes that will be of greatest usefulness to them in meeting the pressing social and economic problems that face the world.[15]

There is a marked sensitivity to some of the "affective" objectives of science instruction in this Yearbook. There is also a more obvious reflection of sensitivity to the responsibility which educators have to prescribe the precise way in which statements of intangible and illusive objectives can be translated into practical programs and to determine how the effectiveness of instruction can be measured.

The most recent document prepared by the National Society for the Study of Education of primary concern to science education was the Fifty-ninth Yearbook which was published in 1960. This Yearbook takes cognizance of the increasing dependence of society on science. The implications for the scientific training of citizens of such a society are clearly considered to be of fundamental importance. The Yearbook goes further than preceding reports of the Society in stressing that characteristic of science which is known as "process" or "inquiry." It is perhaps significant to quote the Yearbook with respect to this latter observation.

> One function of the elementary school has always been to help children learn a part of what they need to know from the world's storehouse of knowledge. In recent years this function has embraced more and more science. Scientific methods of investigation, by which knowledge may be acquired and tested, are now very much a part of our culture. The elementary school should help children become acquainted with these methods.[16]

One may summarize the historical overview by pointing out that the past century has been a century of unprecedented social, economic, scientific, and technological change. The elementary schools are to a very large degree a mirror of the ambient culture, and they are probably more sensitive to social change than any other educational level. They are always, to a degree, consonant with the prevailing philosophies and state of knowledge in existence at any particular time. Fundamental changes in philosophy, in theories of child rearing and educability, in the need for universal and extended educational training for all children and adolescents of our society with capacity to learn, have been accepted within this century. Science, itself, has progressed from the dilettantism of the leisured intellectual to a basic and fundamental activity of a substantial percentage of mankind. No human being of any civilized nation can remain untouched by these multifarious developments. In such a milieu it is not surprising that elementary science instruction has been beset by numerous perplexing problems.

Before proceeding to an examination of specific research studies, it is necessary to comment briefly on the junior high school. To this point very little has been said about science for this particular level. One of the reasons for this is that the junior high school is entirely a twentieth century development; the first such institution having been established in 1910. Until that time and, in fact, very commonly even to the present day, the elementary school embraced grades 1 through 8. Grade 9 was relegated to the high school years. Even today, four-year high schools are most prevalent in rural areas of the country. It was not until the 1920's that junior high schools began to appear in any substantial number. The establishment of curricula suitable for junior high schools has presented problems which certainly are among the most confused and complex in all of education. The science curriculum has reflected this general uncertainty. The junior high school has been a stepchild of American education for more than fifty years. It has all too frequently been discriminated against in terms of facilities, staff, and instructional materials. Institutions of higher learning have not taken their share of responsibility for developing leadership for service at this particular level. The plight of the junior high school partly reflects the historical accident of school organization. Grades seven and eight have too often been considered as an unwanted upward extension of the elementary school, and the ninth grade has been regarded as a vestibule to the senior high school. In spite of the fact that it is essentially an age-level and grade-level where great understanding and skilled instruction are needed, the area has historically been ignored, and there is a dearth of substantial and dependable research which relates to this level. The confusion as to aims, programs, school organization, and facilities has resulted in a shifting, unstable existence for the junior high school. The science curriculum and the problems of obtaining and keeping qualified science teaching personnel for the junior high school have fully reflected this unhappy state.

Overview of Research

The early attempts to conduct research related to elementary school science tended to be of the survey or status variety. Great interest was shown in trying to find out what kinds of experiences were provided in different schools, what specific topics or kinds of content were included, what the goals of instruction were, and whether or not specialized facilities were available. Other status-type studies were designed to discover what training the elementary school teachers had for conducting instruction in science. These studies tended to show, almost unanimously, that elementary school teachers were inadequately trained to conduct science instruction. Survey-type studies tended to fall into disrepute although there are still many examples of them to be found in current literature. In their defense it might be said that valid information relative to the status of a practice, or of some other dimension of science instruction, is frequently a necessary basis for action; however, it cannot be said that such studies ordinarily represent a very advanced level of research.

Another type of investigation was based on some type of analytic procedure. These studies took many forms. Studies representative of this approach include word counts to establish difficulty of vocabulary, and frequency with which certain terms appear; analyses of magazines and newspapers in order to determine what science background would be conducive to understanding of those publications by laymen; and analyses of textbooks and courses of study to determine what topics were being taught and the relative emphasis placed on them.

In recent years more studies have been conducted which attempt to determine the effectiveness of manipulating some pertinent aspect of the instructional environment: *e.g.*, to determine what the effectiveness of various kinds of educational procedures, training programs of teachers, television, films, filmstrips, etc. might have on learning.

One of the thorniest problems that has confronted elementary science has been the difficulty in determining precisely when certain concepts, materials, or ideas, ought to be presented to the students. This has usually been considered in terms of the grade placement of certain concepts, topics, or units. Originally, a basic consideration was the question as to whether or not children could generalize and to what extent, if any, children were able to draw inferences from direct experience. Haupt[17] and Croxton[18] demonstrated that children were able to draw appropriate inferences from observation and other experience. Later work has fully sustained their position. Numerous studies and investigations have been conducted in which an attempt has been made to determine the grade placement of certain scientific concepts. A candid evaluation would be that the results of this research have not been very fruitful in establishing any definite level at which concepts ought to be introduced. In a sense, such efforts seem to have been foredoomed to failure since concepts may be taught at many levels of sophistication; and children, even very young children, may grasp intuitively the most rudimentary forms of fundamental concepts. At the other end of the scale, attaining an advanced understanding of these same concepts may be a highly sophisticated achievement, involving complex quantitative analysis, insight into precise experimentation, and rigorous mathematical proof. While representing very different orders of perception, they nevertheless represent different hierarchies in the understanding of a single concept. Thus, the fundamental question in much of this research should not have been whether a specific concept can be taught; but, rather, to what extent and at what level of sophistication this particular notion can be taught to the children at a given point in their development. Bruner has recently put forward an hypothesis which he proceeds to defend and which also supports the particular argument advanced here. He states:

> We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development. It is a bold hypothesis and an essential one in thinking about the nature of a curriculum. No evidence exists to contradict it; considerable evidence is being amassed that supports it.[19]

If this is a defensible analysis, then problems investigated should not be related to what concepts can be learned, nor to the inherent difficulty of certain concepts (an unanswerable question in all probability); rather, such effort should be directed toward the determination of *which* concepts can make the greatest contribution to the objectives of elementary science instruction. The big question is which concepts are most valuable in the further intellectual development of the child and which contribute the most to the cognitive, affective, and social objectives of science instruction. Perhaps research ought also to be directed toward problems which are involved with the synthesis of simple concepts into more complex ones. What procedures and techniques are most appropriately employed in merging a series of simple concepts into a larger, more comprehensive understanding? How are such insights developed and to what extent are teachers aware of the several basic understandings (simple concepts) which may be required to attain a certain generalized conception (*i.e*, an understanding of the solar system)? The associative aspects of learning can hardly fail to be among the fundamental characteristics of the process of becoming educated, yet studies related to such problems involving science concepts are conspicuously absent from the literature.

Aims and Objectives

The aims and objectives of science education do not represent a field which has been particularly fruitful for research. In part, this reflects the fact that objectives are concerned with philosophies and values which do not yield easily to the research worker's methods. During the 19th century, educational aims were likely to include objectives which were moralistic-religious in character. The purposes which the predecessors of the elementary-science program were to serve included a chaotic admixture of religious indoctrinations, cautionary prescriptions, and wishful thinking. The originators of these earlier programs exhibited massive naivete as to the effectiveness of the instructional program in achieving these aims. Perhaps nothing has been more discrediting to the educational process than the void which has existed between grandiose statements of objectives and the instructional procedures designed to achieve them. There was a tendency toward the indiscriminate stating of objectives and a rather astonishing neglect of descriptions of means by which the objectives were to be realized. In those early days it would have been difficult for a detached observer to relate the activities which he might have witnessed in the classroom to the typical statements of objectives. There was also a notable lack of any calculated attempt to determine the extent to which the objectives so glibly framed were, in fact, achieved. The relatively late development of the evaluation movement and of suitable testing techniques and instruments accounts, in part, for the fact that the statements of objectives were accepted at face value without the embarrassing confrontation of a demand for evidence by skeptics.

It is possible to identify three themes which characterized early statements of objectives. These might be termed religious, utilitarian, and descriptive purposes. Some of these cautionary or animistic characteristics are to be found in current statements of objectives and in programs which still prevail as the following statement attests: "Our age is still replete with remnants of and regressions to such pre-scientific thought patterns as magic, animism, mythology, theology, and metaphysics.[20] Contrary to the spirit of modern science, some such "remnants" still remain in the elementary science program.

The religious purposes included were probably a reflection of our Puritan heritage. An early supporter of nature study states the case for the religious justification of the subject as follows:

> Nature study can develop a child spiritually more effectively than any other subject in the curriculum. If properly taught nature study can teach the child the laws of nature, the vastness of God's universes [sic] and the delicate nicety of balance of everything in the cosmos. Just as soon as we can get a breadth of view in a generation of our young people it will help to solve some of these spiritual problems.[21]

One discussion of the religious orientation of the early objectives of science instruction stated:

> ...It is interesting to note that much of this early [1750–1880] science instruction was...marked by a strong religious note. Particularly was this true in the case of natural history, zoology, astronomy, and geology. The textbooks widely used at that time indicate that their authors utilized facts of the four

sciences in order to prove that the Creator was wise and benevolent, and in order to strengthen the student's faith in a supernatural ordering of natural events...

...Since modern science tends to reject teleological explanations, the use of the sciences "in revealing the wonders of divine creation" is no longer as common as it was in the nineteenth century, but examples of it are still found, not only in classroom practice, but in modern textbooks as well. In some parts of the country where "fundamentalist" religious views are dominant, the teaching of science is designed to help students see a religious purpose in the world...[22]

The following recently published list of objectives indicates both the diversity of purposes which elementary science programs are to achieve and the moralistic and religious emphases which can still be detected.

(1) To give practice in simple observation.

(2) To give practice in purposeful activity.

(3) To enlarge the vocabulary with the names of simple objects and processes.

(4) To give experience in combining the factual and the emotional.

(5) To guide emotional responses away from the highly subjective.

(6) To start habits of scientific thinking in simple matters.

(7) To start building attitudes toward the social effects of science.

(8) To develop simple concepts such as cause and effect, the balance of nature, and the like.

(9) To develop a simple reverence for nature.[23]

Science education has suffered from a plethora of objectives. Long lists of these statements were once fashionable, with specific objectives sometimes running into the hundreds. Statements such as the following were included: "Belief in the value of the truth."[24] This is doubtless a sound and eminently defensible objective; but its peculiar, or unique identification with science instruction is difficult to establish. Description of how this objective was to be attained through science instruction was characteristically lacking.

One early study[25] of the purposes of science instruction in the elementary school was based on an analysis of one hundred and six different educational documents. As a result of the analysis the investigators classified the objectives which they encountered under ten major headings. These were as follows:

(1) Interest the child in his environment.

(2) Utilize the child's interest.

(3) Sharpen the child's power of observation.

(4) Arouse interests that may become hobbies.

(5) Provide for growth in scientific attitudes.

(6) Show cause and effect relationships.

(7) Encourage experimentation.

(8) Encourage initiative.

(9) Develop wider interest in reading.

(10) Provide centers of interest to motivate work.

As the obvious impact of science on society increased, the utilitarian purposes of science instruction began to assume a larger and larger role. It is certainly a predominant theme today. Description continues as one of the functions of science instruction, but it has lost the significance it had in the days when taxonomy and comparative anatomy were leading fields of science study.

The aims and objectives of science instruction were influenced by changing fashions in philosophy and the advances in psychology. These changes tended to move the child more nearly to the front and center of the educational stage. Ancient customs and beliefs relating to the rearing of children were being overthrown, and the heavy hand of authority was coming to rest much more lightly on the young. In addition, through technology, children and their elders were being relieved of the necessity for ceaseless drudgery and toil. Thus, the child moved from being a pawn and a mere object of toleration to a status in which he enjoyed a new freedom and in which he was regarded as a partner in the educational process. To many, there was, and is, a feeling that the movement in the direction of liberation moved much too far, *i.e.*, to the point where the curriculum was based to too great an extent on what the child "wanted to do" and on "what his interests were" rather than on what it might be desirable for him to do. The pendulum has been swinging away from such an extreme position in recent years. There has been the recognition that, although the child is fully entitled to enjoy the dignity which should be accorded to him as a human being, he is, at the same time, a child and must not be deprived of guidance, counsel and a degree of control by responsible adults.

The Thirty-first Yearbook had done much to bring some order into the field. The stand was taken that the major objectives of science teaching were associated with functional understandings of the major generalizations of science and with the development of associated scientific attitudes. From the time of the Yearbook's publication, one is better able to identify the objectives of science instruction with four main areas. These are: knowledge—including facts, principles and concepts; skills involving both intellectual and manipulatory varieties; attitudes; and appreciations and interests.

Since the publication of the Thirty-first Yearbook, controversy has revolved around whether or not "scientific method" is a method which actually exists. It has been argued that students should gain skill in applying the methods typically employed by scientists in conducting their investigations. These methods should be applied by students to problems which they encounter. Protagonists have further argued that "the method" is applicable outside the field of science and have identified various "steps" or "characteristics" of the method.

Curtis, for example, made an analysis based on incidents in the history of science and arrived at "the following techniques which seem to be definitely and characteristically scientific methods. . . ."

(*1*) Locating problems.

(*2*) Making hypotheses, or generalizations, from given facts or from observations.

(*3*) Recognizing errors and defects in conditions or experiments described.

(*4*) Evaluating data or procedures.

(*5*) Evaluating conclusions in the light of facts or observations upon which they are based.

(*6*) Planning and making new observations to find out whether certain conclusions are sound.

(*7*) Making inferences from facts and observations.

(*8*) Inventing check experiments.

(*9*) Using controls.

(*10*) Isolating the experimental factor.[26]

A more recent and complex analysis of the "elements of the scientific method" is reported by Keeslar.[27] This study was validated by the responses of 22 research scientists at the University of Michigan.

The controversy over the "scientific method" seems to be by no means resolved although it is possible that most of the arguments represent semantic difficulties rather than practical or philosophical obstacles. Certainly, authoritative opinion is well represented on both sides of the controversy. It seems certain that many science educators have taken their direction in thinking about this matter from the works of Karl Pearson and John Dewey. Pearson, for example, made the following comment about "scientific method":

> . . . I have endeavoured to point out that science cannot legitimately be excluded from any field of investigation after truth, and that, further, not only is its *method* essential to good citizenship, but that its *results* bear closely on the practical treatment of many social difficulties. In this I have endeavoured to justify the state endowment and teaching of pure science as apart from its technical applications. If in this justification I have laid most stress on the advantages of scientific method—on the training which science gives us in the appreciation of evidence, in the classification of facts, and in the elimination of personal bias, in all that may be termed exactness of mind—we must still remember that ultimately the *direct* influence of pure science on practical life is enormous.[28]

Dewey had commented: "By science is

meant . . . that knowledge which is the outcome of methods of observation, reflection, and testing which are deliberately adopted to secure a settled, assured subject matter."[12] On another occasion he stated:

> Scientific method is not just a method which it has been found profitable to pursue in this or that abstruse subject for purely technical reasons. It represents the only method of thinking that has proved fruitful in any subject—that is what we mean when we call it scientific. It is not a peculiar development of thinking for high specialized ends; it *is* thinking so far as thought has become conscious of its proper ends and of the equipment indispensable for success in their pursuit.[29]

This point of view has been reflected in textbooks and in the literature of science education for more than half a century. An illustration of this view is found in the following statement:

> The scientific method is essentially a method of solving problems that present either a utilitarian or an intellectual appeal; therefore, the true way to induct beginners into its use is to confront them with such problems and guide them in using the scientific method in reaching their solutions.[30]

Conant, writing in his book, *Science and Common Sense*, takes rather strong exception to the notion of such a construct as "the scientific method." He states:

> There is no such thing as *the* scientific method. If there were, surely an examination of the history of physics, chemistry, and biology would reveal it. For, as I have already pointed out, few would deny that it is the progress in physics, chemistry, and experimental biology which gives everyone confidence in the procedures of the scientist. Yet, a careful examination of these subjects fails to reveal any *one* method by means of which the masters in these fields broke new ground.[31]

In spite of Conant's dictum, there are currently authoritative writers who continue to discuss "the scientific method." A recent publication states:

> The practice of scientific method is the persistent critique of arguments, in the light of tried canons for judging the reliability of the procedures by which evidential data are obtained, and for assessing the probative force of the evidence on which conclusions are based. As estimated by standards prescribed by those canons, a given hypothesis may be strongly supported by stated evidence. But this fact does not guarantee the truth of the hypothesis, even if the evidential statements are admitted to be true—unless, contrary to standards usually assumed for observational data in the empirical sciences, the degree of support is that which the premises of a valid deductive argument give to its conclusion. Accordingly, the difference between the cognitive claims of science and common sense, which stems from the fact that the former are the products of scientific method, does not connote that the former are invariably true. It does imply that, while common-sense beliefs are usually accepted without a critical evaluation of the evidence available, the evidence for the conclusions of science conforms to standards such that a significant proportion of conclusions supported by similarly structured evidence remains in good agreement with additional factual data when fresh data are obtained.[32]

As a result of the controversy, there has been a reluctance in recent years on the part of science educators to write much about "scientific method." The terms "problem solving" and "inquiry" have been adopted as euphemisms to cover essentially the same conceptions that earlier statements of scientific method had embraced. It is true that present views tend to reveal a deeper insight into the complex ramifications embraced by the term "inquiry," but to a neutral observer they do not seem essentially different in kind from the conceptions involved in discussions of "scientific method." Whether or not "scientific method" exists, it is certain that considerable research has been devoted to studying what have been thought to be important aspects of such an alleged method. There has also been some tendency to confuse "scientific method" and "scientific attitude." The distinction is made here that "method" implies essentially procedural and operative dimensions, whereas "attitude" reflects a state of mind or a predisposition to respond in a certain way.

Some analyses of scientific attitude have been made. There seems to be less controversy associated with such findings.

Curtis[33] reported the first comprehensive study of scientific attitudes. His report listed such characteristics as the following as indicative of scientific attitude:

(1) Conviction of universal cause and effect relations.
(2) Sensitive curiosity.
(3) Habit of delayed response.
(4) Habit of weighing evidence.
(5) Respect for another's point of view.

Later writers have extended and refined this list but have not notably modified the general construct. There seems to be nearly universal agreement that such an objective is sound and various later studies have been concerned with classroom conditions or procedures designed to attain certain aspects of this objective.

Summary

Perhaps a reasonable synthesis of existing statements of objectives of science education would be that the function of elementary and junior high school science today is to provide knowledge, understanding, and concept development in basic science content. This content should be scientifically honest, represent an intellectual challenge, and should hold appeal for children. It should reveal the nature of science as a process of inquiry. No doubt both scientists and educators could agree rather fully on the summary statement to this point. Educators, however, are much more likely to place greater emphasis than scientists on the fact that science instruction should not be geared solely to these objectives. They would hold that the social aspect of science instruction should not be overlooked. There is not only the body of knowledge which one may have acquired, but there is also the highly pertinent question of how one is disposed to act upon the knowledge he possesses. The scientists, strangely enough, are likely to assume that the behavioral implications will be self-evident, and that individuals will act in a manner consistent with the knowledge learned. Educators are likely to hold that only those things toward which teaching is specifically directed are likely to be accomplished. Therefore, educators would be likely to emphasize that growth of attitudes, appreciations, and interests of the child in positive and forward-looking directions is essential; and that a concomitant of instruction must be a conscious, deliberate, and continuing effort toward the accomplishment of these ends. They are unwilling to base an instructional program solely on subject matter objectives for they are also interested in the behavioral correlates. They would argue that sound instruction must keep the psychological and developmental needs of children in focus.

Curriculum

Content and Grade Placement

An early content study was done by James E. Hillman[34] in 1924 in which he made a determination of the content of science curriculums for elementary school sciences. His study revealed that a wide diversity of topics were considered in the programs from grades one through eight, and that there was very limited agreement as to grade placement of the selected topics. A more recent study of the same general character was undertaken by Dubins.[35] The findings were not really significantly different than Hillman's results published nearly thirty years earlier. For example, Dubins found less than four per cent overlap by grade of the four hundred and seventy-six major topics which he identified in examining 163 grade-courses of study. Still another study of the same general character was conducted by Chinnis.[36] He made an examination of six commonly used elementary science textbooks in an attempt to discover if there was agreement as to which principles should be included. His findings revealed that there was no such agreement among the authors.

Reference has already been made to the comprehensive and definitive study by Craig. This study was based on an analysis of several hundred handbooks, syllabi, and courses of study, and included interviews with administrators, supervisors and teachers. Included among Craig's findings was the statement that "... An examination of the content of courses of study, syllabi and source books of natural science indicated a chaos of goals."[4]

Burns and Frazier[37] reported a study in 1947 based on their analysis of teachers' manuals, syllabi and study guides. They also found no general agreement as to grade placement, or as to the particular scope and sequence of science topics which might be desirable for the elementary science programs.

At the junior high school level, Webb[38] made a comprehensive early study of general science textbooks. He found considerable variation in the percentage of space devoted to the various subject areas; however, physics and physiography were by some margin the most emphasized fields. Studies of the same general character were submitted by Downing (1928),[39] Pruitt (1928),[40] Petit (1940),[41] and many others. Curtis[42] made a synthesis and evaluation of the literature to secure a list of the topics appropriate to general science. He identified 18 sources of data and identified a total of 1,850 separate topics. A complex procedure was employed to determine the relative ranking of the various topics included.

As recently as 1961, Fischler reported on the analysis of eight series of general science textbooks for grades seven, eight and nine and concluded that "little uniformity existed as to grade placement of subject matter materials."[43]

This history of diversity as to topics and grade placement probably stems from failure to develop and maintain any consistent philosophy of the purposes to be attained. Diversity is, of course, not inherently bad but it should at least be justified. The virtues of diversity in the absence of careful evaluation and standards can be extolled as an embroidered cloak for chaos. The evidence appears to be conclusive that there is no agreement on a common core of content or on grade placement of subject matter. It does seem possible that problems of content and placement may have many reasonable solutions and that some flexibility should always prevail. However, there is no reason to suppose that a degree of professional and academic consensus could not be attained through some rational process that would result in the development of some congruence in the science program across the country.

Problem-Solving

A term new in the literature of science education is "process." Precisely what the content of this term as applied to science education may be, is clearly a proper question. A thoughtful appraisal points to the conclusion that although the symbol is new in its application, the import of its meaning is mostly old. It relates to science as a mode of inquiry, as method(s), as a self-correcting procedure for the seeking of knowledge, and as a critical, continuing probing for the truth.

The process aspect of science has recently received much more emphasis not so much because the concept of "process" represents a revolution in educational thought, but rather, because of the prestige which science and science education has suddenly acquired, and because of the large-scale financial support which has recently become available. For the first time, financial resources are available to develop curricula and materials, to provide special programs of teacher education, and to purchase the facilities and equipment needed in a process-oriented program. There can be no doubt of the influence of the work of the Physical Science Study Committee, the Biological Sciences Curriculum Study, the Elementary Science Study and other similar efforts by groups in chemistry and earth sciences. The efforts of these groups are strongly process-oriented and their work seems destined to influence education at all levels for decades.

The process facet of science is placed in juxtaposition to science as a body of verified and organized knowledge. Such a concept of science relates most cogently to investigations concerned with problem-solving. The analyses that have been made provide convincing evidence of the complexity of problem-solving activity: it is indeed "process." Most investigators have, by necessity, taken only one small aspect of problem-solving for critical examination. Only a few of the aspects identified in existing analyses have been extensively investigated.

The Forty-sixth Yearbook presents one analysis of problem-solving which demonstrates many of the facets of the process. Major items in the analysis included:

(1) Sensing significant problems.

(2) Defining problem situations.

(3) Studying the situation for all facts and clues bearing upon the problem.

(4) Making the best tentative explanation or hypothesis.

(5) Selecting the most likely hypothesis.

(6) Testing the hypothesis by experimental or other means.

(7) Accepting tentatively or rejecting the hypothesis and testing other hypotheses.

(8) Drawing conclusions.[15]

The outline above was elaborated in detail for some of the steps. A great many skills are obviously involved in successful problem-solving activities.

Obourn[44] made a study of the assumptions implicit in a selected group of 45 experimental exercises designed for ninth-grade science students. The evidence revealed that: textbooks were inadequate in their provision for the identification and evaluation of assumptions; and the role of assumptions was not significantly related to the total pattern of problem-solving.

In another study, Atkin[45] investigated the ability of children to frame satisfactory hypotheses. In his study, the investigator commented on the paucity of research related to the bases on which children frame their hypotheses, the accuracy of such formulations and the methods employed to obtain them. His comment could be generalized to include a much greater scope for there is a general hiatus of scholarly inquiry in the important area of problem-solving. Atkin's study identified authority, experimentation, observation and "original guesses" as the sources on which the children drew for hypothesizing. He found that children ventured their hypotheses readily although they did not recognize the fact. The investigator noted that younger children relied more on empirical tests of hypotheses and tended to be less dependent on recourse to authority.

These last two findings immediately raise questions: Why should younger children show behavior which is basically more consistent with the spirit of science than older children? Speculation immediately suggests many possibilities which research efforts might either substantiate or refute. Other evidence submitted in this study is strongly suggestive of at least one important aspect of this difference. In "permissive" classrooms children were less dependent on authority and more original (creative?) in formulating hypotheses. They were also more productive in suggesting empirical validation of their ideas. There is a definite indication that a climate must be maintained in the classroom such that children are not afraid to be wrong when they are seeking explanations. At the risk of pontificating, it perhaps needs to be said that a skillful teacher needs to make the point that there are "right" and "wrong" ways to be wrong. One must be sure that teachers understand this distinction or the "right and privilege" to be wrong can degenerate into educational anarchy.

Concepts and Principles

Haupt[46,47] has reported an important series of investigations based on an extensive analysis of responses of children. In one aspect of his studies, the investigator interviewed children in order to gain an understanding of their concepts of the moon. As might be expected, the responses ranged all the way from fantastic to accurate. This range reveals the very great diversity which one might anticipate in a class with respect to the adequacy of the concepts which are held about a single object or phenomenon. A wide variety of responses can be anticipated when children are asked open-ended questions about some specific object or phenomenon. The explanations will include fantastic, magical and religiously-oriented responses; anthropomorphic, enigmatic, and mechanistic explanations; and, of course, essentially accurate accounts.

One of Haupt's[48] studies involved the concepts of magnetism held by children. These concepts were compared with stages in the historical development of the understanding of magnetism, and some remarkable parallels were pointed out. The author comments that "this study of parallels of children's thinking with that of the race reveals primitive ideas that are used to conceptualize the raw data of experience." These studies are valuable because they are indicative of the state of concept development in children and they provide helpful insights that have extensive pedagogical implications.

Young[49] has contributed a more recent study on concepts held by children which are related to atomic energy. Wide variation among children was again demonstrated. A notable sex difference in adequacy of concept was found favoring boys. As the author hints, there may be significant evidence here that the cultural differentiation and expectations for the sexes, even in regard to appropriate interests and fields of study, may start very early and be far more subtle and pervasive than has been anticipated. The dearth of adequate numbers of talented women in science in this country has long been lamented. This study suggests that the origins of many women's general disaffection with science may start very early.

An excellent study has been reported by King.[50] His investigation involved concepts related to length, weight, time and direction; volume and weight; mechanical principles; living things; and shadows. One interesting aspect of the study elaborated on the confusion which language contributes to the difficulty children have in forming adequate conceptualizations. For example, we speak of "live coals," "live wires," and "live matches," but then insist that they are non-living! As children artlessly pointed out, even a dog may be alive or dead. One other difficulty which children had was that their vocabulary was inadequate to the task of verbalizing their understanding.

The studies on concept formation can hardly be more than well started. Nevertheless, the evidence is adequate to suggest that they are potentially of enormous importance. The influence of the teacher and of an efficient methodology of instruction are obviously highly significant for the process of conceptualization. Such questions are raised as: How can teachers build more adequate concepts? How can teachers correct (or provide for self-correction by the students) misconceptions without destroying creativity and fertility of hypothesis? Atkin's study, cited above, showing that older students rely more on authority in hypothesizing, may be indicative of teacher failures at this point. How can teachers identify and analyze the level of the individual child's conceptualization under the pressures of classroom conditions? How can children be guided to avoid magical, animistic, anthropomorphic or supernatural explanations for observed phenomena? Questions such as these seem appropriate for the research worker's efforts.

Identification of science principles which are significant for elementary and junior high school has been a source of study. Robertson[51] compiled a list of 113 principles which were judged to be "appropriate to serve as ultimate goals of science teaching in the elementary school." The process of selection of principles included the composite judgments and contributions of scientists, educators and practicing teachers. Leonelli[52] made a more recent study to determine what principles should be included in the elementary school program. There was some agreement as to which principles should be included but not much agreement as to the specific grade placement.

Smith[53] reported a study which attempted to establish the relative importance of principles of science for inclusion in a general science course at junior high school level. A rather large number of principles (253) were considered by an expert jury to be suitable for use at this level.

Interests

Studies of children's interests in science have been plentiful. It is difficult to identify any consistent patterns which have emerged from many studies. An early report was made by Palmer and Bump[54] relative to the interests of children as reflected by the questions which they ask. Their report is based on a summary of the five years from 1921 through 1925. The questions asked were classified according to the nature of the questions—that is, taxonomy, physiology, morphology, etc., and also with respect to the fields of science represented by the questions. Of the questions asked, zoology was represented by approximately three-fifths of the questions; botany, by a little over one-fifth; and the various other fields of science and applied fields were represented by the rest. A two-way table was also provided which classified the questions in regard to both the type of question and the specific animal or science field to which the question pertained. For example, 5.6% of the questions related to habits of insects, .1% related to the ecology of mammals, 2.3% related to the taxonomy of trees, etc.

Studies in the fields of interests have been summarized by VonQualen and Kambly,[55] and also by Blanc.[56] It is disappointing that no critical evaluation, analysis, or synthesis was included with these resumes. In a study of their own, VonQualen and Kambly used the choices of reading materials which children make as the basis for their analysis.

Baker[57] conducted a study designed to determine what kinds of things pupils ask questions about. The study was based on a total of 9,280 student questions. Of those, 37.7% were classified as being in the natural science area. Biological information was represented most frequently in the questions. The physical science areas which were best represented in the children's queries were "the earth," "astronomy," "energy," and "weather and climate." Some shifts in interest were noted as children moved through the grades.

Zim[58] conducted an extensive investigation of the interests and activities of junior-high age students. His data were derived from a variety of sources including answers to questionnaires, analyses of English papers, and questions asked by students. Perhaps the most significant observation in his study was his noting of the discrepancy between the content of "school science" and the interests of these early adolescents.

Cooley and Reed[59] report a recent technical study of science interests which is based on the activities of 1,045 ninth grade students. The thesis is advanced that the activities an individual has engaged in are a better index of his interests than what he may say his interests are. This study still involves a type of testimony, however, since students reported on their own activities. Of interest here is the fact that the analysis echoes the findings of earlier studies that girls have markedly lower science interests. The study was a factor analysis type and the six largest factors of interest were identified as: (1) a general science interest dimension, (2) a "woodsy," "birdsy" dimension, (3) a science tinkerer dimension, (4) a "thinking about" component, (5) high verbal activity (not necessarily a component of science interest), (6) a "behavioral science" and human body interest. Cooley and Reed indicated the possibility of identifying specific factors with feminine interests.

The report of a study by Fitzpatrick[60] has a sobering effect on anyone who is evaluating interest studies. Fitzpatrick's investigation takes due note of the high evaluation which educational philosophers have placed on student interest. Questions are raised, however, about the "uncritical acceptance of group testimony"; and the blunt conclusion is drawn on the basis of substantial investigation that "testimony gave evidence of being *unstable, inconsistent, ill-considered,* and *unreliable.*" [Italics in the original.]

At the risk of bringing down the wrath of both philosophers and psychologists, one may venture the opinion that there is something inherently untenable in basing curriculum construction on studies of interest. The relationship between motives and interest cannot be denied, and quality learning will result only when pupils *are* interested. However, why interest cannot be developed through instruction, or why it may not follow rather than precede certain experiences, seem to be legitimate and mostly ignored questions. It is obvious that a child cannot be interested in that which he has not experienced directly or vicariously. This view is in no way intended to negate the fact that interests which children have can be used as points of departure for the instructor. The effective instructor will certainly use them as such, but this relates far more to the strategy and tactics of teaching than to curriculum construction.

The interest studies do not provide a basis for much sound generalization. There is pretty clear evidence that biological content carries more appeal than the physical science area. This may reflect the nature study emphasis in the curriculum at the time the early studies were conducted as well as the natural interests of children. With the increase in mechanical contrivances and the increasing remoteness of a "natural" environment, interest patterns of the present and future may be very different. Perhaps one fact which interest studies demonstrate is that children are sensitive to their surroundings, and that their passing interests will reflect this fact. Children live on the cutting edge of culture where the real world meets the world of fantasy. The enthusiasm engendered by their imagination and creative ideas needs to be harnessed skillfully to those aims and purposes of instruction which have been soberly and thoughtfully determined.

Reading

A series of studies on the level of reading difficulty has been reported by Mallinson[61] and his co-workers. These studies included elementary, junior high school, and senior high school textbooks. Difficulty has been measured by application of three different empiric devices known as Flesch, Dale-Chall and Lorge reading difficulty formulas. Herrington and Mallinson have effectively summarized findings from earlier studies as follows:

(*1*) The reading levels of many textbooks in science are too advanced for the students for whom they are written.

(*2*) The differences between the levels of reading difficulty of the easiest and the most difficult textbooks in any area of science are significant.

(*3*) In some textbooks of science whose average level of reading difficulty seems satisfactory, there are passages that would be difficult even for some college students.

(*4*) Many textbooks of science contain non-technical words that could be replaced with easier synonyms.

(*5*) The levels of reading difficulty within the textbooks vary greatly. The earlier passages in the textbook did not seem to be consistently lower in the level of reading difficulty than the later passages.

Using fourth, fifth and sixth grade students, Shores and Saupe[62] report a study on reading for problem-solving in science. They found evidence that reading ability of this type is differentiated from general reading ability. They describe the kind of reading required as "ability to do the type of work-type reading required by problems in science, a reading skill which involves both reading and thinking critically about what is being read . . ."

Reading for problem-solving was more

independent of mental age than general reading ability, which suggests that maturation and cultural impact are not sufficient to develop this skill. More pointedly, special instructional procedures are probably indicated for the development of this skill.

An analysis of the types of reading difficulties encountered by eighth grade students has been reported.[63] Sixteen categories were used in classifying the many types of student difficulties. These included: vocabulary problems such as words not previously encountered, old words used with entirely new meanings (to the student), the same word used in different senses in the same section of writing, and poor quantitative discrimination. In the study reported, examples of words causing difficulty to students because of variation in usage were: "screen," "log," "knot," and "propeller." A real problem in studies of this type is the absence of satisfactory diagnostic instruments which will reveal the particular kind of difficulty experienced by children. It is apparent from this study that a poor general performance can result from quite an assortment of causes.

Enrichment

An extensive investigation by Baar[64] related to the experimental evaluation of the use of enrichment materials in ninth grade general science. Three experimental groups and a control group were established. Three different enrichment procedures were employed and each experimental group was assigned to one of the three methods which were: (*1*) use of differentiated enrichment method, designated the "Activity Method"; (*2*) use of the scientific method, designated the "Problem Method"; and (*3*) attention to the social implications of science, designated the "Social Implications Method." A number of different criteria were employed in evaluation which makes a concise summary difficult; however, in general, the three experimental groups were superior to the control section. The experimental groups differed among themselves in ways which reflected the differing emphases of instruction. In several instances the results are not statistically significant, but the measured differences are in the expected direction. Perhaps the implication is plain that any enrichment procedure which tends to involve pupil-participation is likely to show superior results.

Schultz[65] has completed a study which has broad implications for methodology, problem-solving, and teacher education. She prepared a guide for the study of a biologic community. Criteria which served for directing the preparation of a study guide were: selection of a topic (water-hyacinth community in this case), organization of material, questions, vocabulary, suggested activities and illustrations.

Technology Applied to Science Instruction

There have been a large number of studies which have evaluated the effect of the use of various technological devices on the educational program. Elementary science has shared in this development. The devices have included radio, models, silent film, sound film, television and programmed learning. Through a large number of studies two salient generalizations seem to emerge with regard to all such devices. These are: (*1*) that the wise and carefully planned use of these devices makes a significant contribution to the instructional program; and (*2*) that these devices are instructional *tools* or an *adjunct* to the instructional process rather than *the* instructional process. Films, television, and recently programmed instruction have been proposed as teacher surrogates by some. The evidence appears to be clearly against such a concept for films and television. The debate with respect to the proper role of programmed learning is just beginning.

Brewer[66] reported on a study using radio in New York City's elementary schools. Five "nature" broadcasts were made. Brewer concluded that radio was a useful educational device for: (*1*) stimulating further activity on the part of children; (*2*) transmitting information; and (*3*) affecting attitudes. Carpenter's[67] analysis of teacher reports of radio broadcasts to more than 18,000 fifth, sixth, seventh and eighth grade children in the vicinity of Rochester, New York, resulted in similar findings. The radio broadcasts apparently increased interest in science and made study of textual materials more meaningful. Carpenter noted also that in-service education was indirectly provided for the teachers.

Miles[68] found a significant increase in information about conservation when comparing "radio" classes with "non-radio" classes. Shifts in attitude were more favorable and one grade "radio-class" showed significantly greater interest.

Reiner[69] has reported a study in which television broadcasts on science subjects were transmitted to kindergarten, and first and second grade classes. Reiner concluded that pupil interest in the environment was stimulated, interest was high during and following the telecast, and the programs were highly effective as conveyors of science information. These were judged to be effective in-service benefits for teachers, also.

A study by Smith[70] on ninth grade students compared performance of students who had seen demonstrations performed on film with the performance of students who had seen essentially identical demonstrations performed by their teachers. Differences which prevailed were not significant. This might be taken as evidence that devices need to be used in instructional situations in which they have a unique contribution to offer.

Keislar and McNeil[71] reported a study with first grade pupils who were taught "scientific theory" by use of an auto-instructional device. The emphasis in the study was on helping children acquire a theoretical language which would permit them to explain certain physical phenomena. Each child viewed slides and heard a commentary about the slides through earphones He had t. respond to questions asked, and if correc., received a "green" light which gave "immediate reinforcement" (one of the basic elements which proponents of "machine teaching" constantly stress). The program sequence included 36 slides. The investigators concluded that the children did learn and understand the concepts, that they were interested, and that they had difficulty in verbalizing.

A critic[72] of the Keislar and McNeil study has reacted rather strongly. Because his objections are so basic to much of the current argument about programmed learning, selected comments are reported here.

> Rather than teaching first-graders to "give scientific explanations" (whatever that means); as the authors purport, it seems clear that they have succeeded in teaching a group of children a different vocabulary within which *approved** "animistic, phenomenological, or magical" accounts may be given. Projecting into the future, it is easy to visualize millions of jargonized school children talking "Science" (*e.g.*, electron, proton, molecule, eigen-state, energy level, etc.) as a slick veneer on a mass of ignorance. . . .
>
> Giving a scientific explanation is not synonymous with using scientific phraseology. A productive scientist is not one who learns a pattern of answers, nicely re-enforced, to a predigested set of questions. The mark of a scientist is not the answers he gives so much as the questions he asks. It is important for the child to learn that science and scientific theory do not have all the answers. Perhaps behavior which approximates an experimental environment, where the *child** must ask questions and *do** many things to get *some** answers would be more appropriate.

Goldberg's reaction to the Keislar and McNeil study has some interesting ramifications. In the past, teachers have been confronted with children who were unable to supply the vocabulary which communicated their understanding. With the advent of television, radio, and all theo ther avenues for communication which exist in our culture, it seems possible that teachers will now be confronted with a generation which can

* Italics in original.

mouth symbols fluently—symbols which are essentially devoid of meaning. Whether this danger is real or illusory is a question which has apparently not yet attracted the attention of research workers.

Testing and Evaluation

Recent reviewers of educational research concerned with elementary science have commented that "within the span covered by this review, no published studies dealt with evaluation of student achievement.[73] This statement underscores one of the major problems of the elementary science program at the present time. Since the programs in elementary science have been so amorphous, it had been difficult, if not impossible, to construct satisfactory standardized measuring instruments. Classroom teachers seldom have either the time or the skills for the construction and refinement of precision measuring instruments of their own. Research workers have often been in despair because of the lack of objective measures and have had to fall back on expert opinion, observation, rating scales, or other subjective approaches. Most serious research efforts are confronted with the task of devising suitable evaluating devices.

Boyer[74] reports a comprehensive study of echievement of students in elementary science. He employed an involved procedure in order to classify schools in terms of the adequacy or inadequacy of their science programs. The judgment as to adequacy was based on an analysis of current literature. Expert judgments were obtained to validate the statements of "patterns" of practice which related to science instruction. The statements were ranked in terms of "excellence." Schools were then selected which represented the patterns described. Performance of sixth grade students was then measured on standardized tests. A thorough statistical analysis was completed on total group, on a small matched-pair group of low measured intelligence, and on a small matched-pair group of high measured intelligence. All comparisons favored the "adequate" science group and were statistically significant, except for the high group. This excellent study demonstrates conclusively that the instructional program does make a difference. Boyer concluded that: "Children attending elementary schools with adequate science curriculum patterns, when compared with children in schools having inadequate programs, showed superior achievement . . . ."

Boyer also reports a finding which merits careful consideration. He states on the basis of his evidence that: "Children with high IQ attending schools with adequate science programs showed no clearly significant superiority in science achievement, as compared with equally gifted children attending schools with inadequate programs."

Boyer has chosen to interpret this as evidence that bright children are not so handicapped by mediocre instruction. Exception is taken to this interpretation because it seems to embrace an artifact which is a common one in educational literature. The writer of this document has reported an intensive examination of similar claims elsewhere which illustrate some of the problems.[75] In this case, it seems probable that the measuring devices merely lacked adequate ceiling to measure gifted children. Furthermore, available standardized achievement tests are likely to measure only a small sampling of the learning which presumably accompanies a modern elementary science program. These statements should not be interpreted as deprecating Boyer's fine study. It is one of the best reviewed.

Another kind of study is represented by the work of Matteson and Kambly.[76] The investigation was undertaken to discover if the common complaint of students that they had already had the material being taught is justified in terms of their knowledge and understanding. Conclusions were reached which indicated that the elementary children from a school which included science in grades two through six did no better than children from schools without any organized program. Whether this reflects inadequacy in the testing, or in the elementary science program, or both, is difficult to say. The authors indicated that teachers need to explain the cyclic arrangement of subject matter and to develop in children some understanding of the meaning of "study in depth."

Johnston[77] made an extensive sampling study of elementary school science achievement of fifth-graders. Evaluation devices included: a preliminary questionnaire to superintendents on facilities and procedures; a detailed questionnaire to fifth grade teachers relating to experience, training, teaching resources and other facets of the program for science; a log of science activities; an investigator devised test; and an intelligence test. The investigator reports the "less-than-optimum" conditions as being the emphasis on biological at the expense of physical science and the emphasis on textbook reading and discussion rather than on experimental or laboratory activities, directed observation or "research" reading. The statement is also made that pupils with high measured intelligence did not gain significantly more than other students. The same objection may be made to this last statement as in Boyer's study above, probably to an even greater extent, since the criterion measure was "gain" in a pre- and post-test situation. More serious is the comment that the variance did not increase from pre-test to post-test; although, it is likely that this is also an artifact if the test employed had a limited "ceiling." Given an adequate measuring device, failure to increase the variance of the performance would point perhaps both to failure to differentiate instruction and to failure to motivate gifted children.

A checklist for the evaluation of elementary science programs has been carefully developed.[78] Six criteria were accepted as basic to the objectives of elementary science and the psychology of learning. These included elements of the following:

(*1*) Learning tools of science.
(*2*) Scientific attitudes.
(*3*) Scientific problem-solving skills and aptitudes.
(*4*) Individual differences.
(*5*) Evaluation techniques.
(*6*) Facilities and materials.

Fifty checklist items were designed relating to the six criteria accepted. An example of the items is: "Children use many kinds of written sources of science information." Such checklists are useful in reminding observers of the many dimensions which need to be kept in mind in evaluating a program. Such devices should be useful to practicing school administrators. Checklists suffer from a large element of subjective judgment both in their construction and in their use, and they have, on occasion, been notoriously abused. Still, they may offer great hope for improving the quality of elementary science programs.

At the junior high school level, studies have been made of the comparative performance of ninth grade students in biology classes with the regular senior high school group.[79,80] The results are inconclusive. One difficulty has usually been that "selected" students of junior high age are compared with the general student population of the senior high school. Two questions normally ignored are: first, the possible "Hawthorne effect"; and second, how exceptional the "selected" group's performance might have been if students had taken the work as tenth graders rather than as ninth graders. Previous discussion of concept formation and grade placement would seem to indicate that biology *can* be taught in the ninth grade; whether it should be the *same* course as that taught in the tenth grade is debatable. Limited direct observation has indicated that it is *not* the same course when taught at the two levels.

Teacher Training

One of the criticisms which has been constantly reiterated is that the typical college science course is unsuited to the specific needs of elementary teachers. Teachers have readily testified that formal courses in college science have not contributed in effective ways to improving their instruction of science in their classrooms.[3] Why should this be so? The gap between the college science and the elementary program is typically an enormous one. Teachers have not been helped to transfer their college achievements into an effective elementary school science program. One of the problems also relates to the breadth of information required. The questions which children ask, and their interests, take no cognizance of the artificial boundaries which the academic world has agreed upon. Children will flit effortlessly from astronomy, to zoology, to meteorology, to botany. It is indeed a wise and competent teacher who can cope with these situations. It is also quite evident that requiring specialized courses for the teacher in all the areas represented by children's questions is untenable. This short paragraph outlines a major difficulty in the training of the elementary teacher. Furthermore, on most campuses it is still a major and unresolved problem.

The evidence is also clear that the background of elementary teachers, as a group, in science is inadequate. This is perhaps too innocuous a statement: "appalling" might be more appropriate terminology. Ralya and Ralya[81] conducted a study of the misconceptions held by prospective elementary teachers. Some concept of the problems involved can be gauged by the fact that 69% of the prospective teachers agreed that "the bat is one of several night flying birds"; 65% disagreed with the statement that "if it were not for air all bodies would fall at the same speed"; and 43% agreed that "the seasons are the result of varying distance of the earth from the sun." Reactions were obtained to 240 such statements. Ralya and Ralya's conclusions are quoted in full because of their pertinence:

(*1*) A significant percentage of these prospective teachers exhibited ignorance or misconceptions of many simple and basic facts and principles, knowledge and understanding of which would be necessary for any adequate presentation of elementary science in the classroom.

(*2*) A significant percentage of these prospective teachers believed many folk superstitions, some of them harmful in themselves, and others harmful in that they stand in the way of thinking and rational action.

Although this study is now dated, there is no reason for thinking that the situation is necessarily vastly improved.

Teachers have not necessarily taken the courses which one might expect them to take in order to qualify adequately for elementary science teaching. Davis[82] completed an analysis of the training of 668 Ohio elementary teachers. This analysis revealed that 46.6% of the total science hours accumulated by these teachers were in the fields of geography (30%) and hygiene (16.6%). Among the teachers, only 6.6% had had any credit in physics and 3.6% had no credit in science at all. This group was reputed to be "above average" in the amount of training.

A survey of requirements[83] of several states for elementary teachers indicates that 32 states will certify teachers without any course in science. Interestingly enough, individuals could serve as specialists or consultants in elementary science in 43 of the 48 states without any academic college credit in science. Although this is clearly a deplorable situation, it may be suggestive that prospective elementary teachers and their advisers have been aware of the small contribution which typical college science courses have frequently made toward the teachers' real needs.

Direct evidence that prospective elementary teachers do not know the science they will need to know for effective elementary teaching has been reported in a study by Mallinson and Sturm.[84] One hundred forty-seven prospective elementary teachers were given a standardized general science test. Their performance was compared with performance of high school students on the same test. The results showed that the quality of the high school background of the elementary teachers was important. The prospective elementary teachers who had had their training in one specific high school consistently surpassed the high school group against which they were compared although not at a statistically significant level at the twelfth grade level. Prospective elementary teachers from another high school did not surpass tenth and eleventh grade students at a statistically significant level but were themselves surpassed at a statistically significant level by the twelfth grade group. The interpretations of these facts may be varied but one question that is certainly raised is how much the college courses in science had contributed to the prospective teachers' broad understanding of science. The mean number of college hours of science completed by the group was 15.1 with a median of 14.

McCollum[85] reported a study of the performance of prospective elementary teachers in a professionalized subject matter course in physical science. He concluded that a positive relationship existed between high school science background and success in the course but the relationship was too low to have predictive value. Scholastic aptitude and reading ability seemed more closely related to success in the course.

An inservice program[86] for improving the science instruction given by elementary teachers had been conducted and evaluated. Thirteen two-hour meetings were held during the year in which objectives, content, methods and materials appropriate to elementary science were presented. The instructor and teachers were involved in laboratory activities at each meeting. Evaluation of the effectiveness of the in-service program was on two bases: the comparative performance of students of teachers from the in-service group with the performance of matched control group teachers, and evaluation of the program by the in-service teachers and by principals. The evidence indicated superiority of achievement for students taught by the in-service group. This study is unique because it made a direct attempt to determine if an in-service program is really effective in changing the quality of instruction by measuring the achievement of grade school pupils. At least in this case, the evidence supports the proposition that it does make a difference.

Piltz[87] conducted a study related to the difficulties in teaching science in elementary schools as perceived by elementary teachers. Perhaps the most pertinent aspect here is contained in the observation of the investigator that:

> There is conflict among many conscientious teachers as to content emphasis. This focus is determined in large measure by the teacher's individual interest and competency, administrative pressure, compulsory pupil achievement (namely in reading in lower grades) and environmental conditions.

Considering the fact that most elementary teachers are women who, as a group, have not indentified strongly with the sciences and who, in addition, have relatively limited backgrounds in science, it is not difficult to infer that science instruction may not fare well in comparison to instruction in other fields.

Conclusion

Teaching is a complex act. It is not surprising that progress has been slow in a field involving the immense complexities of both the teaching and the learning processes. In addition, the resources available to support educational research can only be described as miserly compared to the support available to many other fields. In truth, educational research is still at the dilettantism level. There are virtually no full-time research workers in the field. It would be a rash student indeed who would build a professional background of training on the expectation of a career as a research worker in education. The research efforts of most contributors to the literature represent the part-time efforts of individuals whose major commitments of time and energy are to other endeavors. This observation is in no way intended to denigrate the contributions that have been made; it is merely a realistic appraisal of the conditions which prevail. Too often, time for the studies that have been made has had to be stolen from hours that should have gone into recreation, meeting family obligations, or to meeting other professional or community responsibilities.

In addition, when funds have become available, they have frequently been so tied to the *a priori* convictions of the grantors and their ubiquitous committees that little has been accomplished. Education suffers markedly, and perhaps uniquely, from the fact that it is "everybody's business" and it is overrun with self-acknowledged experts whose main claim to special competence seems to reside in the fact that they once attended elementary and secondary schools. Criticism of education has been a vastly profitable occupation for successful critics.

This review should be interpreted in the light of the preceding paragraphs. The review has attempted to examine a portion of the research literature pertaining to elementary and junior high school science. It should provide some insight into the nature of the problems investigated. It has attempted to highlight some of the issues which continue to be debated. It is not a comprehensive review but is believed to be reasonably representative. If the report serves as a vehicle to promote intelligent discussion, to promote better research, to gain more adequate support, to clarify the issues or if it is suggestive of further research which needs to be done, it will have served its purposes.

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The author of this research report states that the primary value in such an analysis is that the investigator is forced to define the learning outcomes desired and to weigh carefully their relative values. It is presented here as a research model—a demonstration of statistical analysis in the solution of a problem in science education. Computations for this study were done in part at the Massachusetts Institute of Technology and Harvard Computing Center.

Predicting Achievement in Chemistry: A Model

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As the final evaluation instrument for the one-year course in high school chemistry at Thayer Academy in Braintree, Massachusetts, the author used the ACS Chemistry Exam, High School, form N. In an attempt to understand and predict the differential achievement among students, a stepwise multiple regression technique was utilized to choose predictors from a battery of tests and inventories.

Using the following tests, a set of scores was obtained on 58 students of the group taking a college preparatory chemistry course during 1960–61:

1. Kuder Preference Record, form C, 10 scales.

2. Science Activities Inventory,[1] 4 factor scales.

3. Otis Self-Administering Test of Mental Ability, form A.

4. American Council on Education Psychological Examination for High School Students (ACE), Q and L scales.

5. Iowa Reading Test.

6. American Chemical Society Chemistry Exam, High School, form N.

The Science Activities Inventory was constructed by the investigator as a way of finding out what kinds of extracurricular science activities were engaged in by his students. The items plumbed such activities as butterfly collecting, ham radio, home labs, and others. The items were factor analyzed and obliquely rotated. The four factors which resulted were interpretable as: (*1*) nature activities, (*2*) mechanical activities, (*3*) mathematical activities, and (*4*) project work (chemistry). The nineteen variable correlation matrix is presented in Table 1.

From this set of correlations a "best" regression equation for predicting the ACS exam score was derived with the following conditions specified:

1. The Kuder Science Scale must be included.

2. No variable shall be included which is not a significant predictor of criterion variance.

The procedure used was to build up the regression equation in a stepwise fashion with one variable added at a time. It was specified that the Kuder Science Scale be included even though it was not the most highly correlated (0.29) with the criterion. The Otis IQ was the most highly correlated (0.54). The next step was to partial out the Kuder Science Scale from the correlation matrix and choose the variable with the highest partial correlation with the criterion. This was between the criterion and Otis IQ. This variable was then included in the regression equation and the significance for the increase in explained variance computed. This process was continued until the increase in variance fell below the 0.20 (arbitrary) probability level. The following regression equation presents the variables in order of their inclusion: